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(54) Method of fabricating an optical fibre having low loss at 1385 nm

(57) A singlemode optical fiber [700] having very low loss at 1385 nm and a practical method for making same are disclosed. A core rod [20] is fabricated using vapor axial deposition to have a deposited cladding/core ratio *(D/d)* that is less than 7.5. The core rod is dehydrated in a chlorine- or fluorine-containing atmosphere at about 1200°C to reduce the amount of OH present to less than 0.8 parts per billion by weight, and then consolidated in a helium atmosphere at about 1500°C to convert the porous soot body into a glass. The consolidated core rod is elongated using an oxygen-hydrogen torch that creates a layer of OH ions on the surface of the rod that are largely removed by plasma etching. Finally, the core rod is installed in a glass tube [40] having a suitably low OH content. Thereafter, the tube is collapsed onto the rod to create a preform [60]. Conventional methods are employed for drawing an optical fiber from the preform and applying one or more protective coatings [75, 76]. The disclosed method is suitable for commercial production of low-OH fiber. Significantly, the fiber's loss at 1385 nm is reduced to a level that is less than its loss at 1310 nm, thereby rendering the entire wavelength region 1200 - 1600 nm suitable for optical transmission. In particular, wave-division-multiplex systems are now available to transmit optical signals over distances greater than 10 km in the wavelength region between 1360 nm and 1430 nm.

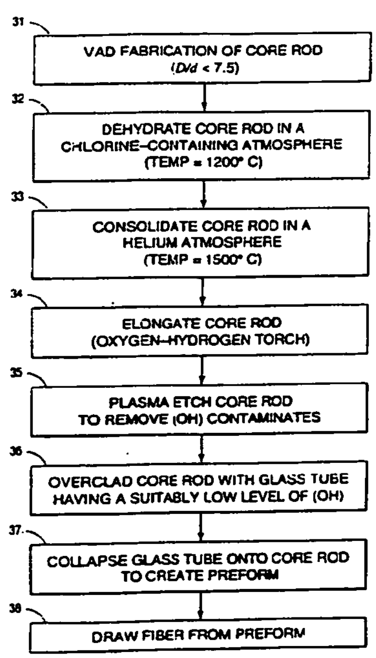

FIG 3

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U.S. Application No. 10/502,455
Attorney Docket No. 11281-044-999
Reference No. B05

ever, low water absorption is achieved by initially depositing a substantial amount of cladding onto the core prior to overcladding with a silica tube. (The VAD process is capital intensive, and any reduction in productivity increases the manufacturing cost to the point that depositing large amounts of cladding are unacceptable for the mass production of preforms.) A figure of merit (*D/d*), known as the deposited cladding/core ratio, has been defined as the ratio of the diameter of the rod (*D*) to the diameter of the core (*d*); and it is desirable for this dimensionless number to be as low as possible because the amount of deposited material is proportional to $(D/d)^2$. Murata reports that the deposited cladding/core ratio is greater than 7.5 before it is overclad with a silica-tube in order to assure low OH content in the fiber for a number of different overcladding tubes. Nevertheless, it is desirable to fabricate a core rod having low OH content wherein *D/d* is less than 7.5.

[0009] It is known to fabricate an optical fiber having low OH content using the modified chemical vapor deposition (MCVD) process such as shown in U.S. Patent 5.397,372 that issued on March 14, 1995. In this patent, a hydrogen-free plasma torch is used for the deposition of high-index material inside a glass tube. The glass tube is then collapsed to become a preform, but only short lengths of fiber (*e.g.*, 0.7 km) can be drawn from such a preform. In commercial production, however, large preforms are required for making long lengths of fiber. And the rod-in-tube technique is a cost-effective way of making large preforms. although OH contamination can be a serious problem.

[0010] Accordingly, what is sought is an optical transmission system that is capable of operating over long distances at wavelengths in the 1360-1430 nm region. More importantly, what is sought a singlemode optical fiber having a low water peak at 1385 nm and a commercially viable process for making same.

[0011] U.S. Patent A-4,737,179 discloses a method of producing a glass preform by first forming a cylindrical rod by the vapour axial deposition method, and secondly by inserting the rod into a glass tube and integrating them by heat. No mention is made of lowering OH concentration.

[0012] U.S. A-5,397,372 describes a method of forming a glass preform substantially free of OH impurities by using a hydrogen-free plasma torch in an MCVD process.

[0013] According to the present invention, there is provided a method as defined in claim 1 or a system as defined in claim 10.

[0014] A process for fabricating a singlemode optical fiber having low optical loss at 1385 nm starts with the step of forming a glass rod having a core whose index of refraction is higher than the index of refraction of a layer of deposited cladding that surrounds it The diameter of the core is designated (*d*) and the diameter of the deposited cladding is designated (*D*). The core rod has a cladding/core ratio that is less than 7.5, and the concentration of OH ions is less than 0.8 parts per billion by weight. The core rod is elongated prior to installation in a hollow glass tube having a suitably low concentration of OH ions. After installation, the tube is collapsed onto the core rod by exposing the tube to a heat source. The resulting structure is referred to as a preform.

[0015] An optical fiber is formed by placing the preform in a furnace and drawing a thin glass fiber from one end. The glass fiber is then coated with one or more layers of protective coating material(s), which are cured by radiation.

[0016] In an embodiment of the invention, the core rod is doped with germanium and fabricated by vapor axial deposition (VAD). Once the core rod is formed, it is dehydrated in a chlorine or fluorine-containing atmosphere at a temperature less than 1300°C, and then consolidated in a helium atmosphere at a temperature greater than 1400°C. A small amount of material is removed from the surface of the rod during etching, which is preferably accomplished using a hydrogen-free plasma torch.

[0017] In one embodiment, elongation of the core rod is achieved using an oxygen-hydrogen torch, which subsequently requires an etching step to remove the layer of OH contaminants on the surface of the rod that are created by the torch. In another embodiment, elongation of the core rod is achieved using a hydrogen-free plasma torch, which does not contaminate the surface of the rod and, hence, does not require a subsequent etching step.

[0018] The inventors are the first to recognize that <u>commercial</u> production of optical fiber having very low OH content is possible; and that this can be achieved using known steps that have never been combined before. Indeed, notwithstanding the long-felt need to use the entire wavelength region 1200 - 1600 nm for optical transmission, and reports of "heroic" experiments during the early 1980's demonstrating that optical fiber can be fabricated with low OH content, no manufacturer commercially offers such a product today!

Brief Description of the Drawing

[0019] The invention and its mode of operation will be more clearly understood from the following detailed description when read with the appended drawing in which:

FIG. 1 shows the overall loss spectrum of known optical fibers, illustrating the losses that attributable to energy absorbed by OH ions at various wavelengths;

FIG. 2 generally illustrates the fabrication of a core rod by the vapor axial deposition process;

FIG. 3 is a flow-chart diagram of a method for making an optical fiber in accordance with the invention;

FIG. 4 shows a plasma torch removing OH ions from the surface of a core rod;

by reference.

[0025] Step numeral 34 in FIG. 3 indicates that the core rod is preferably elongated using an oxygen-hydrogen torch. This is the most cost-effective manner of supplying the large amount of heat needed for this step. Alternatively, this step is carried out using a hydrogen-free plasma torch, as discussed below, and advantageously eliminates the need for etching (step numeral 35). Typically. core rods grown by the VAD process are too large to fit into overcladding tubes of reasonable size, and are usually stretched to decrease their diameter prior to insertion. Stretching is accomplished on a glass lathe whose construction is well known in the art. The core rod is mounted between the headstock and tailstock of the lathe for cojoint rotation therewith. As the core rod rotates, a torch moves below it along its central axis at a constant rate toward the headstock. Simultaneous with the movement of the torch, the tailstock moves away from the headstock, causing the core rod to be stretched to reduce its diameter. Combustible gases, such as hydrogen and oxygen are flowed through the torch at an exemplary rate of 30 liters per minute (1pm) and 15 1pm respectively. And while the use of hydrogen is commercially practical, it creates a layer of OH on the surface of the core rod. Core rod stretching is known in the art and specific details are disclosed, for example, in U.S. Pat. 4,578,101 that issued on March 25, 1986.

Core Rod Etching

[0026] Step numeral 35 indicates that the elongated core rod is etched, preferably with a hydrogen-free plasma torch. FIG. 4 schematically shows apparatus for the plasma etching of core rod 20 to remove a substantial portion of the OH ions that are present on the surface of the rod. Detailed information regarding plasma etching is available in U.S. Pat. 5,000,771, which issued on March 19, 1991 and is hereby incorporated by reference. A brief discussion of the plasma etching process is given below, although it is understood that other etching techniques may be employed to effectively remove OH ions from the rod's surface. These other etching techniques include, but are not limited to, mechanical grinding and chemical etching.

[0027] An isothermal plasma can be used for rapidly removing (etching) silica and silicate glass from the outer surface of a glass rod. With an isothermal plasma torch, the predominant mechanism for material removal is vaporization due to the high plasma temperature, which can typically attain levels greater than 9000°C in the plasma center. Contact of the electrically conductive fireball with the refractory dielectric surface efficiently transfers energy to the surface, and raises the surface temperature above the vaporization point of the dielectric materials thereon.

[0028] FIG. 4 schematically depicts an exemplary apparatus for plasma etching. A torch 10 comprises a fused silica mantle 11 connected both to a gas source 18 by tube 16 and to a gas source 17 by tube 15. Gas source 17 delivers the desired gas used for the plasma discharge into the mantle 11 and through shield 22. The plasma fireball 12 is excited by an RF coil 19 and an RF generator 14. Gas sources are generally used to provide an ionizable gas, with the plasma fireball primarily contained in a confinement region of the torch. A substantial portion of the plasma fireball can be pushed out of the confinement region by adding. to the ionizable discharge gas, a high ionization threshold gas. The additional gas, supplied by gas source 18 and confined to the outer region of the torch by shield 110, creates an area in the upper portion of the confinement region where higher energy is needed to couple RF energy into the gasses to form a plasma. The portion of the fireball outside the torch is typically less than 50%, since maintaining a stable plasma generally requires the plasma center to remain in the torch for sufficient energy to couple into the plasma from the RF source. Additionally, operation with the fireball extended outside the torch by approximately 30% to 50% of its volume generally places greater requirements on the power requirements of the RF source and the flow rate of the gases involved with the process than operation below 30% of the fireball volume. By pushing the plasma center towards the torch exit, the plasma fireball can easily contact the core rod 20. Furthermore, contact is most readily made as the plasma fireball is pushed farther outside the torch.

[0029] The core rod 20 is mounted on a lathe 120 in such a way that the rod can be rotated. Generally, means for mounting and rotating such rods are known to those skilled in the art. Rotating the cylindrical core rod uniformly, with appropriate movement of the plasma torch along the rod, allow material to be removed from substantially the entire surface such that the core rod 20 retains its cross-sectional shape. More importantly, this particular etching technique allows removal of OH ions from the rod surface. In the preferred embodiment of the invention, an etch depth of 0.25 ±0.15 mm is selected. Accordingly, a core rod having a diameter of about 20 mm before plasma etching would have a diameter of about 19.5 mm after etching.

[0030] Gas flow rates into the plasma torch with either O_2 or O_2/Ar as the currently preferred gas, generally range from 1.0 to 100 liters/min. The plasma fireball, excited by an RF generator that typically provides output power between 20 and 40 kW at 3 MHz, for example, traverses the core rod at speeds typically from 0.01 to 100 cm/sec covering about 1 meter of the core rod being processed. Generally, the core rod is rotated between 0.1 and 200 rpm. These conditions can produce etch rates typically in the range from below 0.01 grams/min. to greater than 10 grams/min.

[0031] Overall fiber cost is reduced through the use of larger overcladding tubes. Preferably, the tube comprises synthetic silica, which is known for its high purity, low attenuation, and high tensile strength. The purity of the overcladding tube will determine just how close to

[0036] FIG. 7 discloses a dual-coated optical fiber 700, in accordance with the present invention, after drawing. As shown, two layers of coating materials are applied to the drawn fiber 70, which comprises a light-carrying core 71, deposited cladding layer 72 and over-cladding 73. Glass fiber 70 has a diameter of about 125 μm. It is noted that the relative dimensions of preform 60, shown in FIG. 6, correspond to the relative dimensions of the drawn fiber 70. (Even though the drawn fiber has a diameter that is thousands of times smaller than the preform, it has the same refractive index profile!) An inner layer 75 of protective coating material (primary coating) is applied to the glass fiber 70, and then an outer layer 76 (secondary coating) of protective coating material is applied on top of the primary coating. Both materials are acrylate-based polymers having predetermined hardness ratings. The secondary coating material generally has a relatively high modulus (*e.g.*, 10^9 Pa) to withstand handling, whereas the primary coating material has a relatively low modulus (*e.g.*, 10^6 Pa) to provide a cushion that reduces microbending losses. The secondary coating material may be applied while the primary coating is still wet, and then both coatings are simultaneously cured by radiation in the ultraviolet region of the electromagnetic spectrum.

Performance

[0037] FIG. 8 shows the actual loss characteristic of an optical fiber manufactured according to the invention. The maximum measured loss in the 1385 nm region is less than 0.29 dB/km, which is well below the stated objective of keeping it lower than the measured loss at 1310 nm (about 0.33 dB/km). electromagnetic spectrum.

WDM System

[0038] FIG. 9 discloses a wave-division-multiplex (WDM) system 90 in accordance with the invention. It comprises four transmitters 81-84 that modulate four predetermined wavelengths in the 1200 - 1600 nm region with four different baseband signals. At least one of the transmitters (*e.g.*, 81) operates at a wavelength in the 1360 - 1430 nm region. Heretofore, operation within that "no man's land" has been effectively foreclosed to long-distance optical transmission (*i.e.*, more than 10 kilometers) because of losses attributable to energy absorption by OH ions. The modulated wavelengths are then combined via multiplexer 85 and introduced into an optical cable 900, whose general construction is known by those skilled in the relevant art and disclosed in numerous publications. Illustratively, cable 900 includes one or more fibers including singlemode optical fiber 700 that is manufactured according to the processes described herein and, consequently, is suitable for transmitting optical signals in the wavelength region 1200 - 1600 nm, and which has a loss at 1385 nm which is less than its loss at 1310 nm. At the receiver end, the four-channels are split by demultiplexer 85, according to their wavelengths, and processed by receivers 91-94 to extract the individual baseband signals. Although not shown in FIG. 9, optical amplifiers may be included in the path between the multiplexer 85 and demultiplexer 95. Illustratively, the multiplexer and demultiplexer are passive optical networks.

[0039] Although various particular embodiments have been shown and described, it is understood that modifications are possible within the scope of the invention such as, for example, the fabrication of a core rod by a process other than VAD.

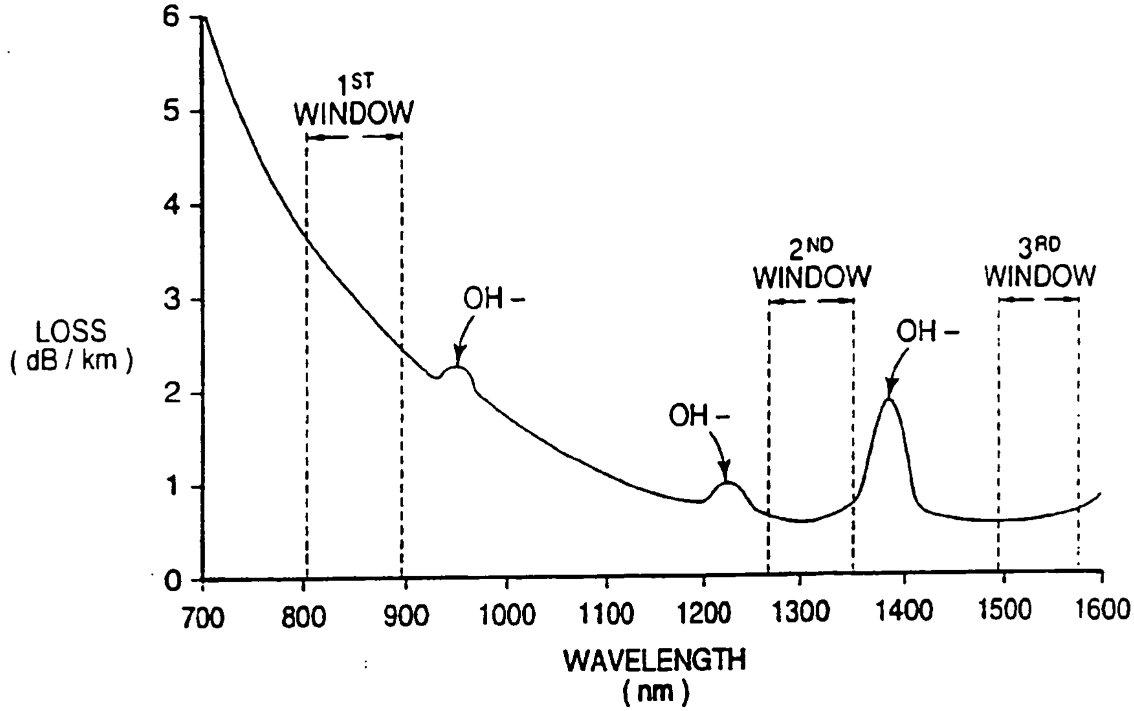
Claims

1. A method of fabricating a cylindrical glass body for single mode optical transmission comprising the following steps:

    forming a glass rod [20] by soot deposition, said rod having a core [21], and a deposited cladding surrounding the core, the core diameter being designated (d) and the deposited cladding diameter being designated (D), wherein D/d<7.5;
    dehydrating the glass rod in a chlorine- or fluorine-containing atmosphere at a temperature, which is less than 1300°C in order to reduce the concentration of hydroxyl ions to a level that is less than 0.8 parts per billion by weight;
    consolidating the glass rod at a temperature, which is greater than 1400°C;
    providing a hollow cylindrical tube [40] having an inside diameter that is slightly larger than the outside diameter of the glass rod, said tube being made from glass having a concentration of hydroxyl ions that is less than about 200 parts per million by weight;
    placing a substantial portion of the glass rod into the hollow tube; and
    exposing the tube to a heat source that moves longitudinally relative to said tube and rod, wherein the heat from the source causes the tube to collapse inwardly upon said rod, whereby a glass preform [60] is created.

2. The method of claim 1 further including the following steps:

    elongating the glass rod [20] using a heat source that contaminates the surface of the rod with hydroxyl ions; and
    removing a substantial portion of the hydroxyl ions for the surface of the elongated glass rod by etching said surface to reduce its outside diameter by a predetermined amount.



(PRIOR ART)

FIG 1

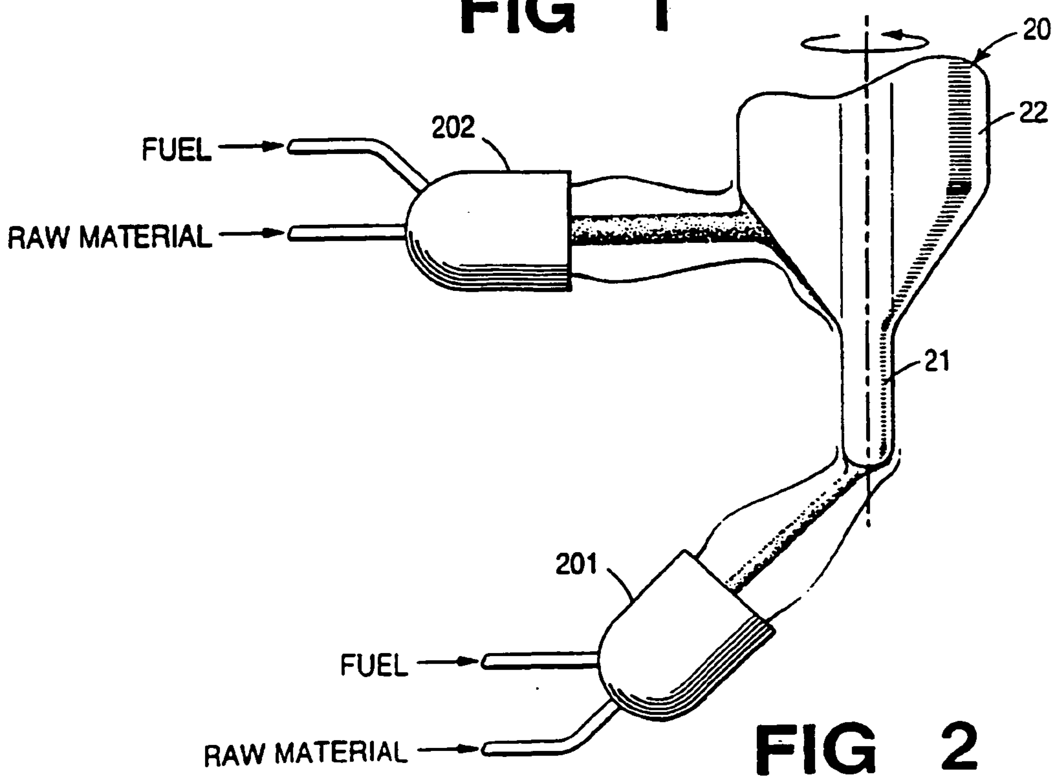
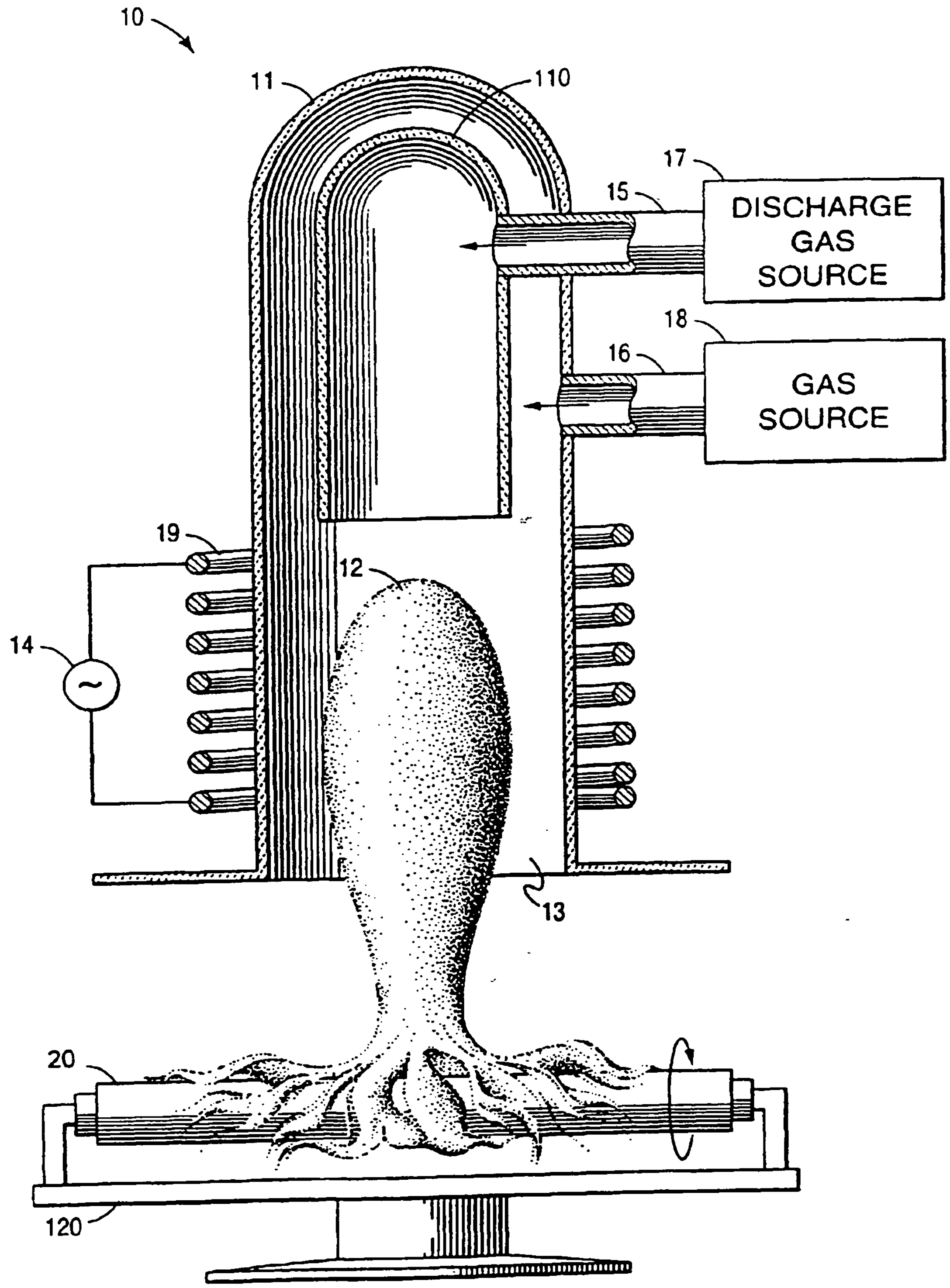


FIG 2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11
110
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DISCHARGE GAS SOURCE
18
16
GAS SOURCE
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120

FIG 4

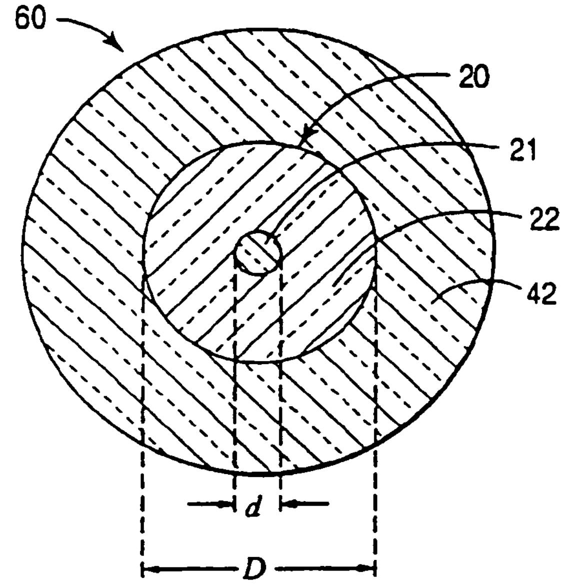

FIG 6

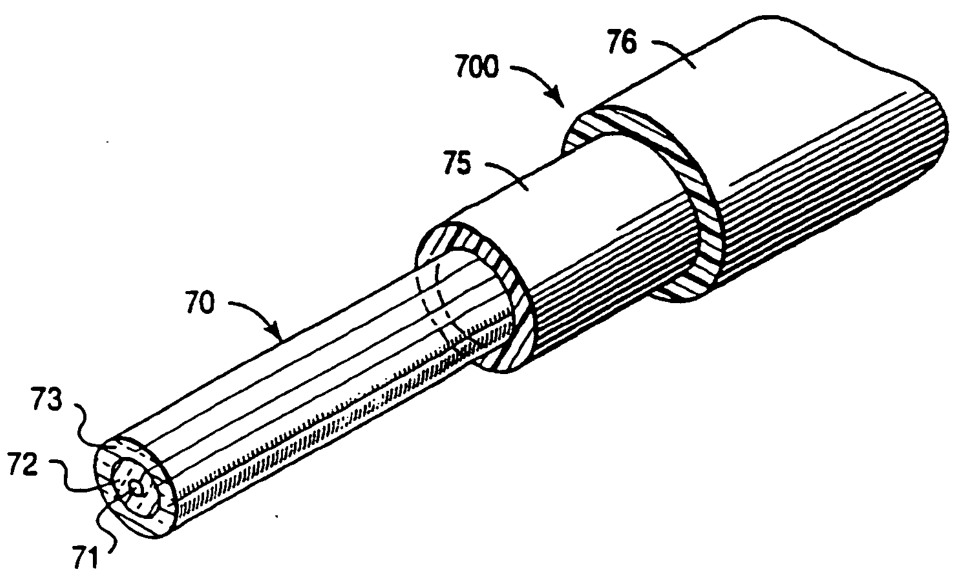

FIG 7